BROWN UNIVERSITY

Providence, Rhode Island 02912

Division of Engineering

30 April 1992

Office of Naval Research
Fluid Dynamics Program (1132F)
800 North Quincy Street
Arlington, VA 22217-5000

Attn: Dr. L. Patrick Purtell
Dr. Edwin P. Rood

Dear Sir:

RE: ONR Grant N00014-90-J-1430 "Studies of Nonlinear Instabilities of Developing Wake Flows Behind Bluff Bodies and their Control"
J. T. C. Liu, Principal Investigator
Progress Report for the period 15 December 1991 to 14 March 1992

The simplified, amplitude equation description of nonlinear mode interactions in spatially-developing two-dimensional far wake flows has been systematically applied to the explanation of the presence or absence of frequency fundamental, subharmonic and first harmonic modes and of two- and three-dimensional modes. The instability modes are all considered to be primary modes in the absence of secondary instabilities; each mode consists of two sub-modes, sinuous and varicose, characteristic of wake flows.

It is found that

(1.) the three-dimensional modes, when present, would decay rapidly downstream, leaving the two-dimensional modes to dominate.

(2.) from energy tranfer considerations, the fundamental mode (which is the sinuous mode) has no energy transfer mechanism with either sinuous or varicose subharmic modes. This is the explanation why subharmonic primary modes are absent in wake flows, in contrast to the much emphasised subharmonics in the mixing region, shear layer flows.

(3.) there is an energy transfer mechanism which exist between the fundamental mode and the first harmonic varicose (but not its sinuous) mode. Comparison of structural shapes with Sato & Kuriki's experiments (J. Fluid Mech. 11, 321-52) indicate that this is indeed the case.

(4.) We used the present simplified framework, which yields streamwise developing nonlinear amplitudes and cross-stream shape functions from local linear theory, to construct the downstream evolution of the vorticity field.

In the experiments of Corke, the three-dimensional subharmonic mode is one due to secondary instability. In order to study this aspect, "accurate" profiles of the primary modes must be obtained. To this end, we are in process of numerically computing the nonlinear spatial development of the primary instability, using hybrid numerical methods.

We are also in process of obtaining the same for an otherwise mean axisymmetric wake. However, in this case, the corresponding "two-dimensional" mode, which is the axisymmetric is always damped in the far wake, leaving the "three-dimensional" helical modes to become active. This is an important difference from the two-dimensional mean wake flows for which only promary two-dimensional modes survive.

Sincerely yours,

J. T. C. Liu
Professor of Engineering
Principal Investigator

Carl Cometta
Executive Officer
Division of Engineering

cc: ONR Resid. Rep./Cambridge
NRL/Washington
DTIC/Alexandria
ORA/Brown University